DESIGN AND DETAILS OF A REINFORCED CONCRETE HARBOR LIGHT HOUSE

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DESIGN and DETAILS

of a

REINFORCED CONCRETE

HARBOR LIGHT HOUSE- -

A Thesis presented by

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SPECIFICATIONS.

For A Reinforced Concrete Harbor Light-House.

Article I.

Section I/ General description of work.

The work will consist of furnishing all materials and labor required to build and erect, at the proposed site, in accordance with the following specifications and the accompanying plans, and under the direction of an engineer appointed by the party of the first part, a reinforced concrete harbor light-house.

Section II. Inspection.

The engineer shall have the right to inspect or to cause to be inspected all materials and labor furnished by the contractor. He shall reject at his discretion any material or piece of workmanship which is not in accordance with these specifications.

Section III. Workmanship.

All workmanship shall be first-class and in accordance with the directions given by the engineer.

Section IV. Cement.

All cement used shall be Portland Cement. It shall be tested by the engineer. It shall be sound, free from all lumps which cannot be readily crushed between the fingers. Its specific gravity shall be not less than 3.10 Briquettes of neat cement, after one hour in water and twenty three (23) hours in air shall show a tensile strength of not less than one hundred seventy pounds per square inch. After one day in water and six days in air they shall show a tensile strength of not less than four hundred fifty (450) pounds per square inch.

Section V. Sand.

All sand used in concrete shall be coarse, clean and sharp.

Section VI. Stone.

All stone used in concrete shall be crushed limestone. The stones shall be as nearly cubical in shape as possible. No stone used in the foundations, up to elevation plus twenty (20) shall be in its greatest dimension too large to pass through a ring two (2) inches in diameter, unless expressly permitted by the engineer.

No stone used in the walls or in floors above elevation plus twenty (20) shall be in its greatest dimensions too large

to pass through a one (1) inch ring. All stone used shall be "crusher run", with the pieces of a larger size than as above specified, screened out.

Section VII. Concrete.

Concrete, where possible, shall be mixed by a mechanical mixer of a type approved by the engineer, or where mixing is done by hand, a method shall be used which will, in the opinion of the engineer, produce results equally good as those produced by the mechanical mixer. No retempering will be allowed. When the work of depositing the concrete is suspended temporarily the surface shall be left rough. Before beginning anew to place concrete the surface of the concrete shall be thoroughly swept off and wet.

Section VIII. Reinforcement.

All reinforcement excepting that in the roof of the keeper's house shall consist of corrugated bars, of the dimensions shown on the plans, of square section. These bars shall be of medium steel, having a tensile strength not less than sixty thousand (60,000) pounds per square inch and an elastic limit not less than one half of the ultimate strength. They shall bend with one hundred and eighty (180) degrees on a radius equal to their own thickness. The reinforcement in the roof of the keeper's shouse shall be of the style known as "Trussit reinforcement".

Section IX. Timber.

All lumber used shall be straight, sound, free from wind shakes, loose of decayed knots, or other defects which may, in the opinion of the engineer, be detrimental to the rapid progress and successful completion of the work.

Article II.

THE FOUNDATIONS.

Section I. General description.

The foundations shall consist of a timber crib enclosing a solid concrete pier extending from elevation minus twenty-five (-25) to elevation plus twenty (20) and resting upon four concrete columns which shall in turn be supported by the bed rock.

Section II. Crib.

The timber crib shall be built on shore according to the dimensions shown on the drawings, and of the materials, and in the manner hereinafter specified. As soon after the completion of the crib as the weather conditions will permit, it shall be floated in place and moored to four stout clumps of piles.

placed as directed by the engineer. Concrete shall then be deposited on the floor of the crib, as rapidly as possible, care being taken that the crib sink evenly, until all six sides of the cutting edge rest upon the bottom of the lake. Air shall then be pumped into the working chamber until the water recedes. Struts shall then be placed under the floor as shown in the plans and excavation shall proceed until the cutting edge has reached elevation minus twenty five and five tenths (-25.5). As soon as the struts are in place, concrete will be deposited in the upper part of the crib until its top is at elevation Zero (0). This concrete shall be deposited as expeditiously as is consistent with the allowance of sufficient head room in the working chamber for the men to work to advantage. When the cutting edge has reached elevation minus twenty five and five tenths (-25.5) the excavation for the lower caissons shall be begun. No excavation shall be done in any well until all the wells previously dug have been filled with concrete up to elevation, minus twenty five (-25).

Section III. Sheathing.

The Sheathing forming the outer wall of the crib shall be of white oak, of the quality described in Article One, Section Nine, of these specifications. It shall consist of three four by twelve inch (4" x 12") planks surfaced on four (4) sides, making a wall twelve inches thick on each side of the crib, extending from the cutting edge to elevation plus five (5). These planks shall be firmly spiked together in the form known as Wakefield sheathing, i.e. the edge of the middle plank shall be at a distance from the edges of the side planks, equal to one half (1/2) the width of each plank. When three planks have been spiked together in the manner above described, they shall be tightly fitted and spiked to the set below and fastened by means of drift bolts to the uprights at the corners and at the middle of each side.

Section IV. Uprights & Interior Bracing.

All uprights and interior bracing shall be of the quality described in Article I. Section Nine of these specifications. They shall be accurately fitted and firmly fastened by drift bolts as shown on the plans.

Section V. Spikes.

Spikes used in the sheating shall be boat spikes of the best quality eleven inches (11") long. They shall in all cases be driven from the inside of the crib. They shall be not more than eighteen (18") inches apart on a line parallel with the edge of the planks and staggered.

Section VI. Drift Bolts.

All drift bolts shall be of a good quality of soft steel, five eights (5/8) of an inch in diameter. They shall be driven

into holes made with an auger nine sixteenths (9/16) of an inch in diameter. They shall be used to connect the sheathing and rangers to the uprights and at all joints in the interior bracing. Where drift bolts are used to connect sheathing with rangers, holes shall be bored from the inner side of the ranger to a point within one (1) inch of the outer side of the sheathing. The drift bolt shall then be driven well home into these holes. At all other points the drift bolt shall penetrate through the entire thickness of the timbers to be fastened together and, where there is room, shallproject and be bent over against the side of the timber.

Section VII. Roof of working chamber.

The roof of the working chamber shall be of reinforced concrete three feet three inches (3' 3") in depth. It will be built as shown in the plans and in accordance with the specifications for concrete in Article One, Section Seven and Eight. It shall be firmly tamped. The top surface shall be left rough. It shall be given at least one month to set before the crib is floated in place.

Section VIII. Rings in lower caissons.

The rings in the lower caissons shall be of the best quality medium steel having a tensile strength not less than sixty thousand (60,000) pounds per square inch and a modulus of elasticity not less than half of the ultimate strength. They shall be accurately centered and shaped in the form of a circle and care shallbe taken in hauling them so that they may not be sprung out of shape. Any rings or parts of rings which the engineer may reject shall be immediately set aside and removed at the earliest opportunity from the site of the work.

Section IX. Lagging in lower caissons.

The lagging to be used in the lower caissons shall be of hardwood three by six inches (3" x 6") in section, surfaced on two sides and matched. Any knot extending the entire width of the piece shall cause its immediate rejection. No set of lagging shall be of greater length than four (4) feet excepting by special permission of the engineer. There shall be at least two)2) steel rings used to brace each set of lagging.

Section X. Lock shafts.

The lock shafts shall be of riveted steel pipe with flanges as shown on the drawings. A gasket of good quality of rubber shall be used at each pair of flanges. These flanges shall be tightly bolted together and an iron washer shall be provided with each bolt. Care shall be taken to insure a tight fit between the trap door of each lock and the floor above it.

Section XI. The tie rods in upper part of crib.

The tie rods shall consist of medium steel dock rods one and one quarter (1 1/4) inches in diameter. They shall be placed as shown on the plans. They shall be provided with button heads, nuts and washers. The holes, in the timber, through which they pass shall be bored with an auger of the same diameter as the rod.

Article III.

The Keeper's House.

Section I. General description.

The keeper's dwelling shall rest directly on the foundations. It shall conform in all respects to the dimensions shown on the drawings.

Section II. Walls.

All walls shall be of concrete of the quality described in Article I. Section III. of these specification. Both interior and exterior walls shall have a facing of grout one-half (1/2) inch in thickness on both sides. The grout shall be a mixture of one part cement to two parts sand.

Section III. Doors.

The outer door shall be of a good quality of sheet steel, built up as shown in the drawings.

Section IV. Windows.

All windows shall be of a good quality of plate glass of double thickness.

Section V. Window frames and sash.

All window frames and sash shall be of heavy, pressed galvanized iron, built up according to the dimensions and in the manner shown on the drawings.

Section VI. Floors.

The tower floor shall be of moorish tile laid on the concrete foundation. The floor of the store room shall be of reinforced concrete. It shall rest on the walls of the house and of the tower. Two I - Beams shall also be used as shown in the drawings.

Section VII. The Roof.

The roof of the dwelling house shall be of reinforced concrete. The reinforcement shall be of the trussit type and

shall conform to the specifications of the "General Reinforcement Company" for that type of reinforcement.

Article IV.

The Tower.

Section I. General Description.

The tower shall rest directly on the foundations and shall be firmly anchored thereto by steel rods as shown on the drawings. The wall shall be of rinforced concrete with at least one half (1/2) inch facing of grout.

Section II. Tower Stairway.

The steps of the stairway shall be of cast iron with the upper sides corrugated. These steps shall rest upon iron risers and shall be firmly fastened to them as shown on the drawings. These risers shall be cast with collars which fit around the main steel column.

Section III. Railing.

The stairs shall be provided with a railing which shall be of one (1) inch cast iron pipe supported on brackets, anchored to the walls by means of anchor bolts embedded in the concrete while the walls are being built.

Section IV. Main Column.

The main column shall be a circular steel shell, built up in sections of the dimensions shown in the plans. The joints in this column shall be made by means of flanges and these flanges shall be securely bolted together.

Section V. Window Frames.

All window frames and sash shall be of the best quality heavy pressed galvanized iron.

Section VI. Watch room floor.

The watch room floor shall be of reinforced concrete conforming in quality to the descriptions given in Article I of these specifications. The floor shall be covered with a good quality of Moorish tile. It shall be supported by the tower wall and by six brackets of reinforced concrete as shown.

Section VII. Watch room Port-holes.

The port holes in the watch room shall be of plate glass They shall be framed with brass and hinged at the sides in order to be opened.

Section VIII. Watch room stairs.

The steps shall consist of corrugated steel plates connected by angle irons to steel plates bent in the form of a helix. All shall be accurately fitted as shown on the drawings.

Section IX. Railings.

The railings and uprights shall be of brass tubing, bent and accurately fitted as shown on the drawings.

Section X. Lantern Room Floor.

The lantern room floor shall be of plain concrete floor resting on steel I Beams which are, in turn, supported by the watch room wall. The concrete shall conform to the description given in Article I. Section III. of these specifications, and care shall be taken to place the I Beams in their proper location as shown on the drawings.

Section XI. Glass in lantern room.

All glass shall be of the best quality plate glass of double thickness, bent accurately to the radius shown on the drawings. It shall be fastened by a suitable clasp to the frames.

Section XII. Frames in lantern room.

The frames for the glass in the lantern room shall consist of T Bars. These T Bars shall be embedded in the concrete wall and shall extend through into the lantern room floor.

Section XIII. Railings.

The railings on the balcony of the lantern room shall be of wrought iron pipe of a good quality, bent to the proper form and supported on wrought iron uprights, imbedded in the concrete floor.

Section XIV. Flue above lantern.

The flue above the lantern shall be of a good quality, galvanized iron, extra heavy and securely built as shown on the drawings.

Section XV. Lantern room roof.

The roof of the lantern room shall be of steel plate. Sections of the roof shall be bent to the shape shown on the drawings and riveted together before the roof is raised above the floor of the lantern room.

Section XVI. Fittings above roof.

All fittings above the roof shall be of a good quality of gray iron, accurately cast as shown on the drawings.

COMPUTATIONS.

for

REINFORCED CONCRETE

HARBOR LIGHT-HOUSE.

Cast iron weighs 470#/ cu. ft. = .27#/ cu. in.

Weights.

Weight of spire = $\frac{\pi \times 2 \times 2}{4 \times 1728} \times 24 + \frac{\pi \times 1^2 \times 2.5}{4 \times 1728} = 5.661$ #

Weight of collar above spher = $\frac{\left[\frac{\pi}{4} 2^2 - \frac{\pi}{4} 1^2\right] \times 2 \times 470}{1728} = 1.28$ #

Weight of sphere = $\frac{4\pi}{3}\left[10^3 - 4.625^3\right] \times .27 = 125$ #

Collarbelow sphere = $3.142\left[5^2 - 4.625^2\right] \times 3 \times .27 = 9.186$ #

Weight at pedestal

Taking sections $1\frac{1}{2}$" apart diam ters are $9\frac{1}{4}$", $13\frac{1}{2}$", $14\frac{1}{4}$", $8\frac{3}{4}$", $9\frac{3}{4}$", 19", 23", 24"

Weight of pedestal = $\frac{.7854\left[9.25^2 - 8.5^2\right] + .7854\left[13.5^2 - 12.75^2\right]}{2} \times 1.5 \times .27$

$+ \frac{.7854\left[13.5^2 - 12.75^2\right] + .7854\left[9.25^2 - 8.5^2\right]}{2} \times 1.5 \times .27 + \frac{.7854\left[9.25^2 - 8.5^2 + 8.75^2 - 8.00^2\right]}{2} \times .7854 \times 1.5$

$+ .7854 \times 1.5 \times .27 \times \frac{8.75^2 - 8.00^2 + 9.75^2 - 9.00^2 + 9.75^2 - 9.00^2 + 14.00^2 - 13.25^2}{2}$

$+ .7854 \times 1.5 \times .27 \times \frac{14.00^2 - 13.25^2 + 23.00^2 - 22.25^2 + 14.00^2 - 13.25^2 + 23.00^2 - 22.25^2}{2}$

$+ .7854 \times 1.5 \times .27 \times \frac{23.00^2 - 22.25^2 + 24.00^2 - 23.25^2}{2} + .7854 \times \frac{3}{8} \times .27 \times \left(24^2 - 18^2\right)$

$+ .7854 \times 11.25 \times .27 \times \left(9.25^2 - 8.5^2\right) = 95.98$ #

Weight of cover-plate.

Circumference of base of cone = $2 \times 57 \times 3.142 = 358$"

Circumference of circle into which would be developed $2 \times 72.31 \times 3.1416 = 454.4$"

Slant height of cone with plate taken out = $\sqrt{8.00^2 + 12.00^2} = 14.5$

Weight of plate = $\frac{358}{454} \times 3.142\left(72.31^2 - 14.5^2\right) \times \frac{3}{8} \times .281 = 1066$ #

Total weiht acting on plate = $5.661 + 1.283 + 125 + 9.186 + 95.98 + 1066 = 1310$ #

$\angle$ plate makes with vertical = $\tan^{-1}\frac{57}{38} = 56°19'$

Stress in plate = $\frac{1310}{\cos 56°19'} = 2365$

Horizontal compont = $2365 \sin 56°19' = 1965$ #

Weight of window and sash = $(6.1667 \times 2.5833 \times .0208 \times 10 \times 196) \div 100 = 720$ #

Diameter of circle furnishing reaction = 8'-6"

Circumference = 26.7036' = 320"

Stress per" = $\frac{1965}{320} = 6.2$ #

To tal tearing stress due to steady load = $6.2 \times 8.5 \times 12 = 632.4$ #

Assume f at 12000 # per sq. in. in order to allow fo wind stresses.

As

Assume $\frac{3}{8}$" plate

$$632.4 = 12000 \times \frac{3}{8} L$$

$$L = .07055\ ''$$

Weight of Ts.
10-10½' Ts. @ 3.7#/ft. = 195#
Weight of all acting on floor excepting lantern = 2220#

Lantern Room Floor.

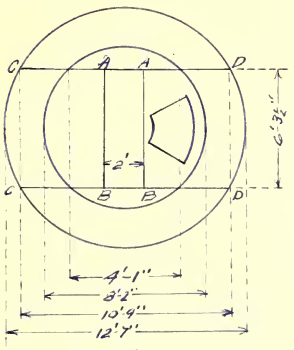
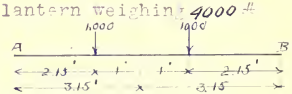


Fig I

Assume weight of floor sections resting on CD. then AB support only lantern weighing 4000 #



Bending moment = $(4.5-2) \times 1000\#$ = 2500
f_s = 13000 #/□"
Z = 1.98
Use a 4" 7½ # I Beam where Z = 3

Then assume a floor 8" thick

Length of outside arc of hole for stairway = 4'

Length of inside arc = x
$\frac{x}{4} = \frac{1.5}{3.5}$; x = 1.71'

Area of hole = difference in area between △ OFF & OGH = A
$A = \frac{(1 \times 3.5) - (3 \times 1.71)}{2} = 3.72\ \square'$

Weight of floor = $[(3.142 \times 6.25) - 3.72] \times \frac{8}{12} \times 150 = 11,500\#$

Since part of this load goes directly to the wall, it will be safe to consider the total floor load evenly distributed over the beams CD

Concentrated load from lantern = 1000 # at each I beam AB.

Concentrated load above, including roof = 585 #

Rc = $\frac{11900}{2x2}$ + 555 + 1000 = 7355 #

Max. M = 12 [(1955.3 x 5.45) − (550 x 5.45 x $\frac{5.45}{2}$) − (555 x 2.05) − (1000 x 1)]

Max. M. = 174180 in. lbs.

Z = $\frac{174180}{13000}$ = 13.4

Use an 8"-18 # I beam

Weight of railing around lamp

Length of railing = 37.6992'

1½" Wrought iron pipe weighs 2.68#/ft.

6. railing posts of 1½" pipe 4' high

Total weight on = [(3 x 37.6992) + (6 x 4)] x 2.68 = 376 #

Total weight on wall = (9 x 4553) + (4 x 10.9 x 18) + 370 = 19367 #

Radius to outside of watch room wall = 6'

Height of watch room = 8'3" = 8.25'

Radius of lantern room = 4'-2" = 4.1667'

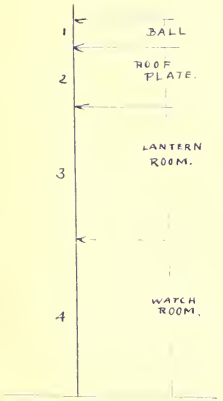
Height from lantern room floor to bottom of plate = 10'-3½" = 10.2917'

Height of roof plate = 2'6" " = 2.5'

Radius of roof plate at base = 4'-9" = 4.75'

Diameter of ball = 22" = 1.8333'

Area of ball under pressure = 190 □" = 1.32 □'



Wind pressure = 50#/ ft.

Sec I, pressure = 1.32 x 50 = 66 #

" 2 " = ½ x 4.75 x 2.5

" 3 " = 50 x 10.2917 x 4.1667 = 2144 #

" 4 " = 50 x 8.25 x 6 = 2475 #

Moment section I = $66 \times \frac{(8.25 + 10.2917 + 2.5 + 1.83)}{2}$ = 1950 ft lbs

Moment section 2 = $247 \times (8.25 + 10.2917 - \frac{2.5}{2})$ = 5881 ft lbs

Moment section 3 = $2144 \times (8.25 + \frac{10.2917}{2})$ = 28730 ft. lbs

Moment section 4 = $2475 \times \frac{8.25}{2}$ = 10210 ft. lbs

To-tal overturning moment = $1750+5281+2878+10210 = 46271$ ft. lbs
Height of center of pressure from line AB = $\frac{46271}{66+297+2144+2475} = 9.288'$

To tal
Total pressure = 4982
Total weight tending to prevent over-turning = 19370 + weight of wall

Assume watch room wall 6" thick
Weight of wall = $(113.276 - 95.033) \times 7.5833 \times 150 = 20550$ #
Total weight tending to prevent over-turning about section A = $20550 + 19370 = 39920$ #

Point of application of resultant

x = distance of point of application of resultant fr from center $\frac{x}{4982} = \frac{9.288}{39920}$ $\therefore x = 1.16'$

Since resultant comes within middle third of base, no reinforcement will be required.

Wind stress on each bracket = $\frac{m}{3r} = \frac{46271}{3 \times 5.75} = 2685$ #

Dead load compression on one bracket = $\frac{39920}{6} = 6655$ #

Total compression on one bracket = $2685 + 6655 = 9340$ #
Depth = 6" With = $\frac{9340}{6 \times 300} = 5.2''$

M = $\frac{5}{6} dA f_s$ d = 1.5' - 1.5" f_s = 13000 #

$9340 \times 1.5 \times 12 = \frac{5}{6} \times 18 \times 13000 \times A$

A = 0.862 □"

Use 2 - $\frac{3}{4}$" Round bars for reinforcement in compression.

Watch Room Floor

Weight of steps = $10 - \frac{3}{8} \times 5 \times 25\frac{5}{8} \times \frac{490}{1728} = 120$ # cast iron
Weight of plates supporting steps (steel) =

$\frac{490}{1728} \times [(11 \times 10\frac{8}{32} \times 4\frac{3}{8} \times \frac{3}{8}) + (167\frac{33}{64} \times 9\frac{3}{8} \times \frac{3}{8})] = 130$ #

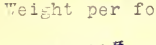
Weight of railing =

$2 \times 11 \times 10\frac{8}{32} \times 0.7854 \times 1 \times \frac{490}{1728} + (2 \times 167\frac{33}{64} \times .7854 \times 1 \times \frac{490}{1728}) + 4 \times 36 \times .7854 \times 1 \times \frac{490}{1728} = 200$ #

Total weight of stairs = $120 + 130 + 200 = 450$ #

Assume weight of stairs act at center of two beams 6" deep
Unsupported length = 11'
Weight per foot = $\frac{1}{2} \times 1 \times 1 \times .150 + 100 = 175^{\#}$

Allow $100^{\#}$ load on each step



Watch Room Floor (continued)

Reaction = $\frac{175 \times 11}{2} + 225 + 350 = 1325^{\#}$

M. max = $[(1325 \times 5.5) - (175 \times 5.5 \times 2.75)] \times 12 = 55704$ in.lbs

$M = \frac{5}{6} dAf_s$

$\frac{3}{4}$"square corrugated bars

A=area of reinforcement per foot

$d = 6 - 2\frac{3}{8} = 3\frac{5}{8} = 3.625''$

$f_s = 13000$

$55704 = \frac{5}{6} \times 3.625 \times 13000 \times A$

$A = 1.419 \square''$ Spacing = $\frac{12.5625}{1.419}$

Area of $\frac{3}{4}$"$\times \frac{3}{4}$ bar = $\frac{9}{16} \square'' = 0.5625 \square''$ spacing = $\frac{3}{4}$" C. to C.

Number bars per foot = $\frac{1.419}{.5625}$

Walls under Watch-room

Total compression = at bottom of watch room floor = $39925 + (\frac{1}{2} \times .7854 \times \pi^2 \times 150) + (100 \times 7854 \times 11^2) \div 1000$

Total load = $58010^{\#}$

If wall under watch room floor is 6" thick then radius to C. G of wall = 4.25'

Area = $2 \times 4.25 \times 3.1416 \times \frac{1}{2} \times 144 = 1922 \square''$

Stress per sq. in. = $\frac{58010}{1922} = 30.17^{\#}$

Weight of brackets = $[(\frac{1}{2} \times \frac{5.2}{12} \times 1.5) + (\frac{1}{2} \times 1.5 \times 1.5 \times \frac{5.2}{12})] \times 150 \times 6 = 730^{\#}$

H = depth in feet to which 6" wall is allowable

$\frac{58010 + 730 + (3.1416 \times 8.5 \times .5 \times H \times 150)}{1922} = 300$

$H = \left(300 - \frac{58740}{1922}\right) \times \frac{1922}{3.1416} \times 8.5 \times .5 \times 150$

$H = \frac{517860}{1922} \times \frac{192.2}{3.1416 \times 8.5 \times 5 \times 150}$

$H = 268.5'$

Make walls 6" thick to base of tower.

Vertical Reinforcement. in wall of tower
Depth 10' between watch room floor
Overturning moment =
(66 x 31.9554) + (297 x 29.7917) + (2144 x 23.3959) + (2975 x 14.125) + (4500 x 5) = 118591

Total horizantal pressure above joint =
66 + 297 + 2144 + 2975 + 4500 = 9982 #

Height of point of application of resultant horizontal pres- above given plane = $\frac{118591}{9982} = 12.5'$
Moment to be resisted by vertical reinforcement is M. = 118591 x 12
= 1423000 in. lbs.
Figure the rods as forming a hollow shell
Then M. = fZ $z = \frac{.0982\,(d^4 - d_1^4)}{d}$

d = outside diameter = 8'-8" = 104"
d_1 = inside diameters =
Then M. = $\frac{18000 \times .0982\,(104^4 - d_1^4)}{104}$

Depth 10'
M. = 1423000 in. lbs.
$d_1 = \left(\frac{1988000000 - 1423000}{17}\right)^{\frac{1}{4}} = 103.96$

Use $\frac{1}{2}$" x $\frac{1}{2}$" rods 6" C. to C.
A = 3.1416 x 103.96 x .04 = 13.1 □"

Depth 20'

Bending moment = [(9982 x 22.5) + (10 x 9 x 50 x 8)] = 235845 ft. lbs.
Total horizontal pressure = 9982 + 4500 = 14000 #
Height of Center of Pressure above joint = $\frac{235845}{14000} = 16.9'$
M. = 235845 x 12 = 2830140 in. lbs.
$d = \left(\frac{1988000000 - 2830140}{17}\right)^{\frac{1}{4}}$
d = 103.95"
t = 0.05"
A = 103.975 x 3.1416 x 0.05 = 16.4 □"
Use $\frac{1}{2}$" x $\frac{1}{2}$" rods spaced 5" C. to C.

Depth 30'
Bending moment = (14000 x 26.9) + 22500 = 399100 ft. lbs.

Total horizontal press. to - 18500 #
Height of Center of pressure above joint = $\frac{399100}{18500} = 21.6'$

M. = 399100 x 12 = 4789200 in. lbs.
$d = \left(\frac{1988000000 - 4789200}{17}\right)^{\frac{1}{4}}$
d = 103.93"
t = 0.07"
A = 103.965 x 3.1416 x .07 = 22.9 □"
Use $\frac{1}{2}$" x $\frac{1}{2}$" rods spaced $3\frac{1}{2}$" C. to C.

Depth 40'

Bending moment = $(18500 \times 31.6) + (4500 \times 5) = 607100$ ft. lbs.

Total horizontal pressure = $18500 + 4500 = 23000$ #

Height of C. P. $\frac{607100}{23000} = 26.4'$

Bending moment = $607100 \times 12 = 7285200$ in. lbs.

d = $\left(\frac{1988000000 - 7285200}{17}\right)^{1/4} = 103.89''$

t = $104.00 - 103.89 = \frac{1.7}{17} 0.11''$

A = $103.945 \times 3.1416 \times .11 = 35.94 \square''$

Use $\frac{1}{2}'' \times \frac{1}{2}''$ rods spaced $2\frac{1}{4}''$ C. to C.

Reinforcement in tower wall

Depth 50'

Bending moment = $(23000 \times 36.4) + (4 \times 9 \times 50 \times 8) = 851600$ ft. lbs.

Total horizontal pressure = $23000 + 1800 = 24800$ #

Height of C. P. = $\frac{851600}{24800} = 34.3'$

Bending moment = $851600 \times 12 = 7819200$ in. lbs.

d = $\left(\frac{1988000000 - 10219200}{17}\right)^{1/4} = 103.85''$

t = $104 - 103.85 = .15''$

A = $103.925 \times 3.1416 \times .15 = 49.00 \square''$

Use $1'' \times 1''$ bars $6\frac{5}{8}''$ C. to C.

Depth 60'

Total horizontal pressure = 24800 #

Height of C. P. = 44.3'

Over-turning moment = $44.3 \times 24800 = 1098640$ ft. lbs

Moment = $1098640 \times 12 = 13183680$ in. lbs

d = $\left(\frac{1988000000 - 13183680}{17}\right)^{1/4} = 103.81''$

t = $104.00 - 103.81 = .19''$

A = $103.905 \times 3.1416 \times .19 = 62 \square''$

Use $1'' \times 1''$ rods $5\frac{1}{4}''$ C. to C.

Depth 65'

Total horizontal pressure = 24800 #

Height of C. P. = 49.3'

Over-turning moment = $49.3 \times 24800 = 1222640$ ft. lbs.

Moment = $1222640 \times 12 = 14671680$ in. lbs

d = $\left(\frac{1988000000 - 14671680}{17}\right)^{1/4} = 103.79''$

t = $104.00 - 103.79 = \frac{1.7}{17} .21''$

A = $103.895 \times 3.1416 \times .21 = 65.6 \square''$

Use $1'' \times$ " bars $4\frac{3}{4}''$ C. to C.

Design of living room roof

Horizontal distance from center of tower to outside end of ridge rib = 12.5'

Horizontal distance of valley rib = 7.00'

Height of end ridge rib from horizontal plane of outer end of valley rib = 9.00'

Distance from outside end of ridge rib to outside end of valley rib = $(9.00^2 + 7.00^2)^{1/2} = 11.42'$

Distance from point where ridge and valley ribswwould meet if produce (: e : center of tower in same horizontalpplane with ridge rib). to outside end of valley rib = 16.91'

.Angle made at center of tower between ridge and valley ribs = $\tan^{-1} \frac{11.42}{12.5} = 42°30'$

Radius of tower = 4.5'

x = difference between length of valley rib and distance between outside end of valley rib and commoniintersection

$\cos 42°30' = \frac{4.5}{x}$

x = 6.1'

Load lenth valley rib = 16.91 - 6.1 = 10.81'

Distance between inside end of ridge and valley = y

$\frac{y}{4.5} = \tan 42°30'$

y = 4.12'

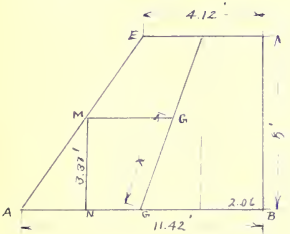
Loaded length of ridge rib = 12.5 - 4.5 = 8.00'

Area of trapezoid = $\frac{11.42 + 4.12}{2} \times 8 = 62.16$ □'

Then each section of roof is very nearly a trapezoid as shown in the figure.

Center of gravity is on line from BCD at a distance from AB from = to $\frac{h}{3} \cdot \frac{a + 2b}{a + b}$ where

h = CD = $(8^2 + 3.26^2)^{1/2} = 8.8'$



b = EF = 4.12'

a = AB = 11.42'

$\bar{x} = \frac{8.8}{3} \times \frac{11.42 + 8.24}{11.42 + 4.12} = 3.71'$

$GK = \frac{3.71 \times 8}{8.8}$

GK = 3.37'

AE = 10.81'

$\therefore AM = \frac{10.81 \times 3.37}{8.8} = 4.14'$

AM = 4.14'

Then the loads from two sections of roof may be assumed to

to at a distance = 4.14' from the wall of the house .
Use We will use a concrete roof 2" thick reinforced withtrus-
sit reinforcement ; will stand a load of 166 #/sq. ft.
2 x area of trapezoid x thickness x weight per foot of con-
crete and 2 x area of trapezoid x weight per sq. foot of trus
sit
Load on each valley beam = $(2 \times 62.16 \times \frac{2}{12} \times 150) + 2 \times 62.16 \times 23' = 3200$ #
Now the effective length of the valley rib acting as a rib
is the length of the horizontal projection H of the rib .

But the length of that projection as scaled from the drawing = 10'
Let θ = ∠ valley rib makes with horizontal

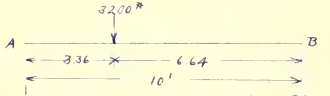
Then $\tan \theta = \frac{9}{12.5} = 0.7200$

$\theta = 35^\circ 50'$

x = horizontal distance of point of load from outside wall

$x = \cos 35^\circ 50' \times 4.14$
x = 3.36'

THEN we have the equivalent of a beam as shown in the following figure



$R_A = \frac{3200 \times 6.64}{10} = 2125$ #
M max = 2125 x 3.36 x 12 = 85680 in. lbs.
M = fz use 6" I 12 1/7 # I beam in. lbs.

85680 = 16000 Z ∴Z = 5.36

Use a 3" - 5 1/2 # I beam in ridge for stiffening.

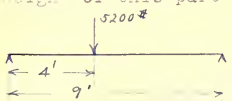
Design of floor above living room
assume the greatest stress to come on a beam located 3' from
outside wall as shown in the figure
Length = 11.5' Live Load = 200 #/□'
Assume floor 6" thick
Then dead load = 75#/sq? ft. Total = 275 #/□'
Bending moment = $\frac{275 \times 11.5 \times 11.5}{8}$ = 10,100 in. lbs. per ft. W
Using I" rods 2" from bottom
$M = \frac{5}{6} dAf_s$ d = 3.50 " , f_s = 16000
∴ 10,100 = $\frac{5 \times 3.50 \times 16000 A}{6}$

$A = \frac{6 \times 10,100}{5 \times 3.50 \times 16000}$ = 2.34 per sq. in. = 2.34 rods per foot

Center of pressure of floor acting on I beam is 4' from outside wall, weight of floor = $\frac{4.5 + 14}{2} \times 7.5 \times .5 \times 150 = 5200\#$

Center of gravity of trapezoid outside of point where load is considered concentrated is 2.3' along beam from outer point of support

Weight of this part = $\frac{10.50+14}{2} \times 3.75 \times .5 \times 150 = 3445\#$



Then we have a beam thus;

M max = $\frac{[5200 \times 5 \times 4}{9} - 3445(4-2.3)] \times 12 = 68400$ in.lbs.

f = 16000 M = fZ Use a 5" 9.75 # I beam

$\therefore Z = \frac{68400}{16000} = 4.27$

Design of Foundation.

Total pressure from wind above living room = 24900#
Height of its C.P. above surface = 40.3+20 = 69.3'
Total horizontal pressure = 29 X 21 x 50 = 30450#
Height of C.P. above water surface = 30.5'
The highest wave registered on the great lakes was fifteen feet above the surface of still water and the greatest pressure recorded is 2000#/sq. ft.; the total height of the wave being 23'

When striking at the horizontal pressure occurs when such a

Thrust from wind on piers alone = 50 X 5 X 48 = 12000#
Weight of C. P. above surface of still water = 17.5'
Pressure from wave portion above datum = 15 X 48 X 2000 + 1440000 #
Height of C. P. above datum = 7.5'
Total horizontal pressure above datum = 24000 + 30450 + 12000 + 1440000 = 1,507250#
Height of C. P. above datum =

$$\frac{(24800 \times 69.3) + (30450 \times 36.5) + (12000 \times 17.5) + (1,440000 \times 7.5)}{1,507,250} = 9.07'$$

Total weight above El. + 20 = $58010 + \left\{ \left[\frac{(3.1416 \times 12^2 \times 8^1)}{4} \times 3.1416 \times \pi \right] \times 8.25 \times 150 \right\}$

$+ \left[(.7854 \times 9^2 - 7854 \times 8^1) \times 65 \times 150 \right] + \left[\frac{18.6^2}{12^2} \times .7854 - .7854 \times \frac{6\frac{1}{2}^2}{12^2} \right) \times 65 \times 470 \right] + 87 \Big[$

$\left[\frac{2.75+18}{12} \times \frac{1}{48} \times 333 \times 470 \right] + \left(47 \times \frac{13}{12} \times \frac{1}{48} \times 3.67 \times 470 \right) + (6 \times 3200) + (6 \times 12.25 \times 10.81) +$

$+ (6 \times 5.5 \times 8) + \left[\left(\frac{13.1}{144} \times 10 \right) + \left(\frac{16.4}{144} \times 10 \right) + \left(\frac{23.9}{144} \times 10 \right) + \left(\frac{35.9.9}{144} \times 10 \right) + \left(\frac{49}{144} \times 10 \right) + \left(\frac{52}{144} \times 10 \right) + \left(\frac{68.6}{144} \times 5 \right) \right.$

Total weight above E.L. + 20 =377I55#
Weight per foot of pier below E.L. + 20 = 6 X $\frac{24}{2}$ X 21 X I X I50 =226800#

Area of pier = I5I2 /sq. ft.
Total weight above datum = 377I50 + (20 X 226800) = 4,9I3i50
Cu. ft. of water displaced = $\frac{I5I2}{2}$ X I5 = II340 cu.ft.
Weight of water displaced = 62.5 X II340 = 708750 #
Effective weight tending to resist overturning = (9I3I50) - 708750 =4,204200#
Total horizontal pressure above datum = I,507,250#
Height of C. P? =9.07'
Let x =distance from axis which resultant strikes

Then $\frac{I507250}{4204400} = \frac{x}{9.7}$

.: x = 3.5

Therefore resultant comes 1/2 inside the middle fourth
Let W. = weight required above datum to make resultant just cut center edge of middle fourth
Then x =5'

Total horizantal pressure = I507250#
W = total vertical pressure

9.7 = height of C. P.
.: $\frac{I507250}{W} = \frac{5}{9.7}$

W = 2924035
Cubic feet to be left as pockets in foundations =

$\frac{4204400 - 2924005}{20}$ =6337 cu. ft.

Total area of horizontal section $\frac{8537}{20}$ =425 sq.in.

At bed of lake : E.L. - 20'
Depth of wave below datum = 3'
Max. horizontal pressure from below E. L. 0. is (8 X 20X48) +(I2 X62.5 X$\frac{2I}{2}$ X 48) =768000+ 378000=II46000#

Height of C.P. of above pressure above lake bottom =$\frac{768000 XI6 + 378000x 6}{II4600}$ = I2.7

Total horizontal pressure above lake bottom = I507250 + I46000

$$-\frac{(62.5 \times 144 \times 49)}{2} = I507250 + II46000 - 220500 = 2432750\#$$

Height of C. P. of Total pressure above lake =

$$\frac{(1507250 \times 29.07) + (1146000 \times 12.7) - (220500 \times 4)}{2,432,750} = 20.63'$$

Let W = weight required above bed of lake in order that resultant come within middle fourth.

Then $\frac{W}{20.63} = \frac{2432750}{5}$

.: W=II503I90#

Area of pier = I5I2 sq. ft.

.: Weight of water displaced = I5I2 X 20 X 62.5 = I890000#

Total weight in air required above bed of lake = II503I90 + I890000 = I3393I76#

Weight of concrete required below datum = I3393I76 - 2921065 = I0469III

Depth of soil required below datum to prevent overturning = D

Then since area of pier = I5I2 sq. in.

.: I5I2 D X I50 = I0469III = 69'

$$D = \frac{I0469III}{I5I2 \times I50}$$

If we leave no pockets the new weight required above datum = = I3393I76 - 492I50# = 8,900,026 Weight below datum required

Depth required below datum = D

$D = \frac{1512DX150}{8480026} \quad D = 37'$

Coefficient of friction between timber and clay = 0.2

Area of concrete required to support structure weighing I3,393,I76 = sq. ft.

Using a I : 2 : 4 mixture f = 800 sq. in.

$A = \frac{I3393I76}{800 \times I44} = II6.$ sq.in.

If we use 2 cells area of one cell= 58.7 sq.

d =diameter

$d = \sqrt{\frac{38.7}{.7854}} = 7'$

If the whole pier is sunk to a depth of 5' below lake bottom
Then total weight of structure (-25) is 491350+(25X1512X150)=
10583150
Weight below EL. -25 = 1[illegible] - 10[illegible]150 = 8[illegible]
H = depth of walls below bottom of crib
Then:113 H X 150 = 8[illegible]
H = 180'too much

If we place a 12' cell in the center beside the 8 - 8' walls
Then : [(3.1416X6X6)+116]150 X H = 2810026

∴ H = 8[illegible] = 85'
219 X 150

3 - 8' cells and a 12' cell
∴ (113 + 3X 4 X 4 X 3.14[illegible])150 X H = 2[illegible]
H = 72'

Use 3 - 8' cells and 1 - 12' to rock

Working Chamber

Pressure per square foot at top of chamber = 20 x 62.5 =
=1250#
Pressure at bottom = (1[illegible]+ 3 X 12[illegible]) = 1 [illegible]# sq.ft.
Average pressure = $\frac{1250 + 1[illegible]}{2}$ = 15[illegible]# /sq.ft. vertically

$\frac{q}{p} = \frac{1 - \sin}{1 + \sin}$

Assume 0 = 20° for soft filling
Horizontal pressure per sq. ft. = $\frac{1 - .[illegible]}{1 + .[illegible]}$ X 15[illegible] =[illegible]# /sq. ft.
Total pressure on one side of crib = 24 X 5 X 370 = 88[illegible]#

Bending moment per vertical foot = $\frac{370 \times 12 \times 12}{3}$ = 19[illegible]

Using oak shoring, f = 800#/sq. in.

$Z = \frac{I}{6}$ bd b =12" M = fZ ∴ 19 720 = $\frac{800}{6}$ X12 d^2

$d = \sqrt{\frac{6 \times 198720}{800 \times 12}}$ = 11"

Use -8" - 4" X 12" White oak.

Working Chamber Ba cing .

Stress = P = 40000# on each ranger

S= area of cross section

f = safe compression stress of pine = 700#/ sq.in. for white pine

l = length = I2' = I44"

h = smallest dimension of piece

$$\frac{P}{S} = f - \frac{f}{I00} \times \frac{l}{h}$$

Use an 8" X I0"

Stress on each ranger = 4000#

Then $\frac{40000}{S} = 700 - \frac{7 \times I44}{8} = 574$

S = 70 sq. in. area required

Area of an 8" X I0" piece =80sq. in.

Use 8" X I0 " pine for rangers

Stress on radial bracing = 47000#

Try a I0" I0" pine wood.

$$\frac{47000}{S} = 700 - \frac{7 \times I8 \times I8}{I0} \quad = S = 79$$

I0" X I0" will do.

Members of inner hexagon l = 8" = 96 "

Try an 6" X I0"

$$\frac{47000}{S} = 900 - \frac{7 \times 8 \times I2}{8}$$

S = 77 sq. in. area required

Area of piece = 80/s .in.

Ceiling of Working Chamber of Crib

Weight required to sink caisson =62.5 X 20 (8 X $\frac{24}{2}$ X 23 $\frac{I}{I2}$)=

= 2077500#

"E shall hav I - 4'lock 4' in diameter ov r each hole or well

Th lock shaf's will be $\frac{I}{2}$"steel plate

Then the weight of steel2in lock will b (4 X 25 X 3II4I8 X I $\frac{II}{I2}$ X I $\frac{II}{I2}$) 490 = 50640#

Weight of concrete required = 2077500 - 50640# =2026900#

Weight of concrete p r vertical foot = (6 X $\frac{24}{2}$ X 20 - 50.26)

X I50 =208350

Depth of concrete = $\frac{2077500}{208350}$ = 9.97'

Since sufficient concrete must be deposited as soon as the caisson is floated in placeWe must have a floor of sufficient strength to sustain that weight per foot =10 X150 = 1500#

Let us make this ceiling of reinforced concrete 3' - 3" deep on shoe

When d = 3'

$$M = \frac{1500 \times 40 \times 40}{8} = 300000 \text{ ft. lbs.}$$

$$M = \frac{5}{6} dAf$$

$$\therefore \frac{300000 \times 6}{5 \times 3 \times 16000} = 700/\text{ sq. in. of steel per foot}$$

Using 2" corrugated rods we required $\frac{7.5}{4} = 1.875$ rods per foot

Spacing them at 6 $\frac{3}{8}$"

The reactions necessary to sustain this floor may be supplied by false braces until the caisson is launched. The reaction will then be supplied by the cheap bearing of the mat until the working chamber is pumped dry when a sufficient number of posts may be inserted to sustain the weight of the superstructure.

Making no allowance for the stability of the concrete mat in reaction as a beam before more concrete is placed above, and assuming that the timber in the working chamber must sustain the entire weight, we shall figure the quantity of timber required.

Total weight to be supported = (10 X 900750) + 70000 =

9075000 lbs. Use 38 - piles

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ON
E HARBOR LIGHT-HOUSE.
OTHERS AS INDICATED.

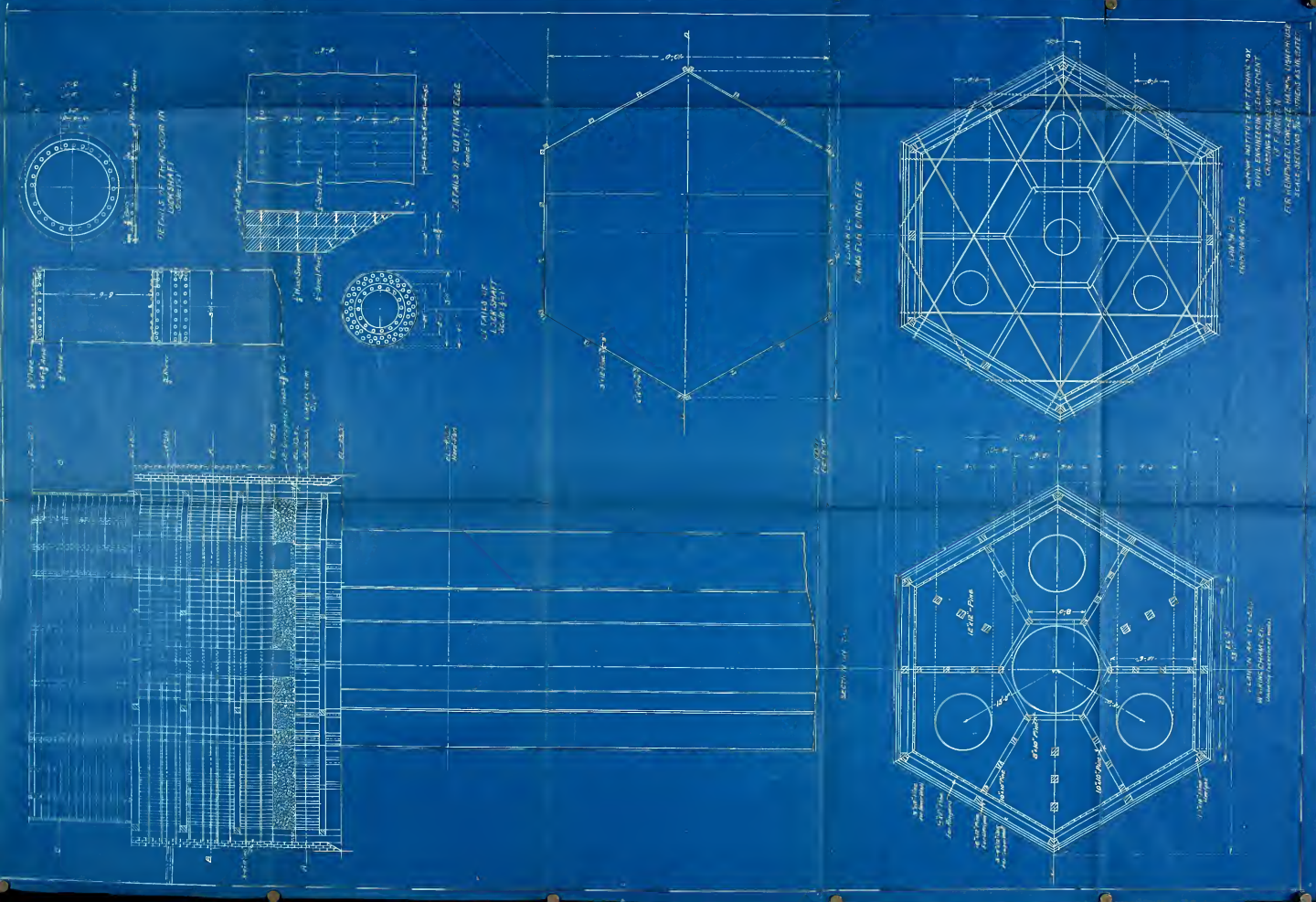

FIG. 1
LANTERN ROOM FLOOR.

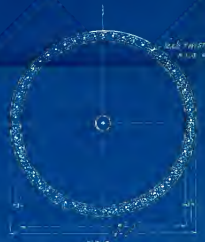

FIG. 3
SECTION AT EL. 75'-9"

FIG. 4
SECTION AT EL. 65'-0"

FIG. 6
WATER SHED

FIG. 5
SECTION AT EL. 52'-0"

FIG. 8
DETAILS MAIN STAIRS

FIG. 2
LANTERN ROOM

FIG. 9
TOWER WINDOW

FIG. 7

FIG. 11

FIG. 14
MAIN DOOR

FIG. 10

WATCH CLIMBER BRACKETS
FIG. 12

HAND RAIL ANCHORING
FIG. 13

SECTION OF DOOR

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CIVIL ENGINEERING DEPARTMENT
SECTIONS, DETAILS OF
TOWER, MAIN STAIR, WINDOWS & DOOR
FOR REINFORCED CONCRETE HARBOR LIGHT HOUSE
SCALE — 1/2" & 1/2"-1


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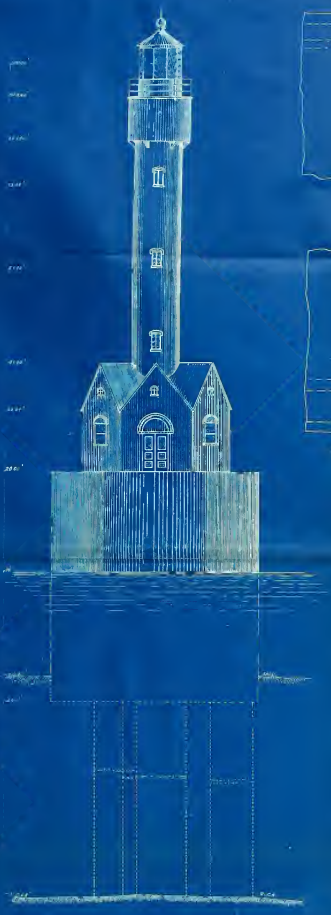
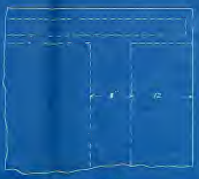
DETAILS OF
LIVING HOUSE.
ETE HARBOR LIGHT-HOUSE
PLAN 1/4"=1' ELEVATION 1/8"=1'



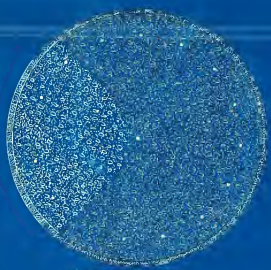


ELEVATION OF RIDGE.

SECTION OF RIDGE.

RIGHT ELEVATION OF VALLEY.

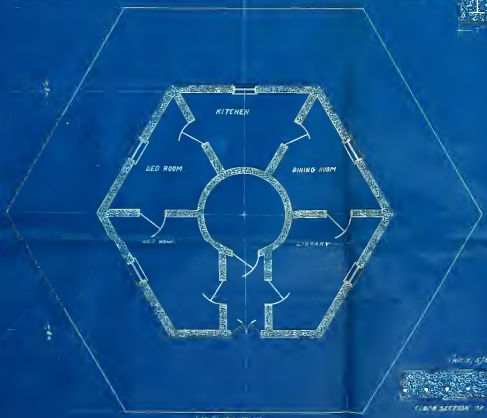
RIGHT SECTION OF VALLEY.



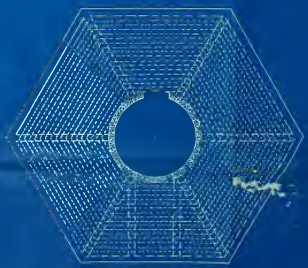
12' CAISSON SECTION.

8' CAISSON SECTION.

SPARK BARN FLOOR PLAN.



1st FLOOR PLAN.



SECOND FLOOR PLAN.

FLOOR SECTION OF SECOND FLOOR

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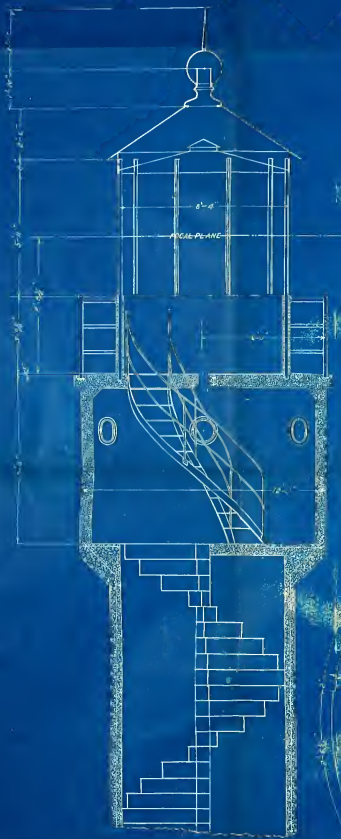
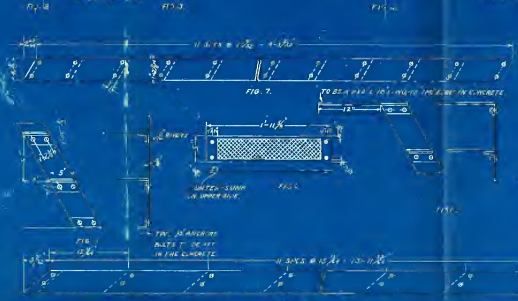
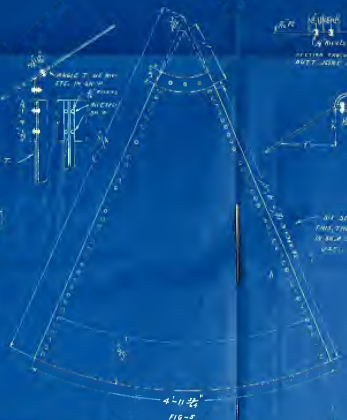
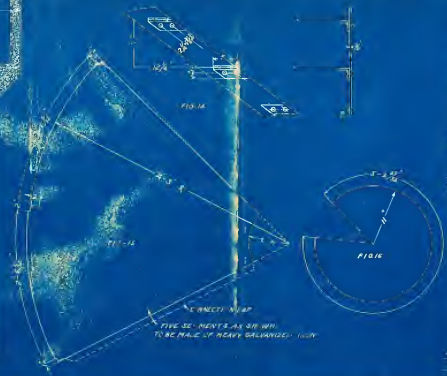
ELEVATION & DETAILS OF
LIGHT-HOUSE & LIVING HOUSE.
FOR REINFORCED CONCRETE HARBOR LIGHT HOUSE
SCALE SECTION 1/8"=1'-0" PLAN 1/4"=1' ELEVATION 1/8"=1'

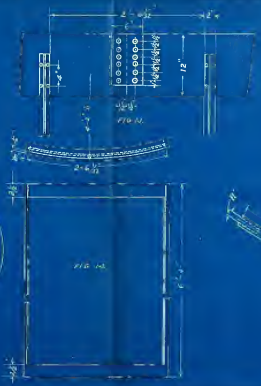

5/16" PL
7/8" Rivets
SECTION THROUGH

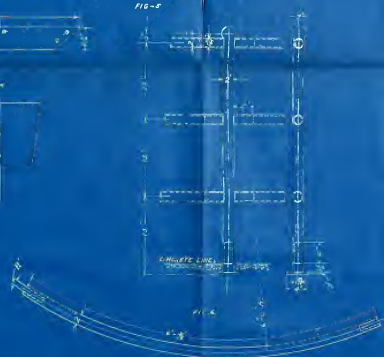












ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
SECTION & DETAILS OF
LANTERN HOUSE & WATCH CHAMBER
FOR REINFORCED CONCRETE HARBOR LIGHT-HOUSE
SCALE — SECTION 1/8" = 1' DETAILS 1/2" = 1'